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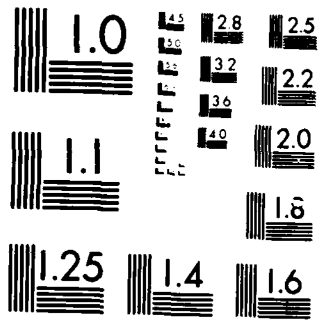

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A THEORETICALLY BASED REVIEW OF THEORY AND RESEARCH IN JUDGMENT AND DECISION MAKING

Kenneth R. Hammond

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Barriers to unification lie in the false dichotomy and rivalry between intuition and analysis, the arbitrary choice of task conditions, and the absence of a theory of successful intuition, as well as in current research practices. A theoretical framework is presented that is intended to overcome these barriers. The theory is anchored in task conditions, specifies the variety of cognitive properties they induce, and indicates subsequent behavior.

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In a first step toward the unification of research and theory in judgment and decision making, Hammond, McClelland and Mumpower (1980) described and compared, in a theoretically neutral context, six major approaches to current research problems. Anderson, Deane, Hammond, McClelland and Shanteau (1981) subsequently compiled a comprehensive glossary of concepts in the field. This article, which introduces a unifying theoretical framework, is the third step toward the goal of unification.

My purpose is (a) to identify and examine obstacles to unification, (b) to present a comprehensive view of cognition so that the work of various researchers can be interrelated, and thus (c) to assist the study of cognition to become a cumulative science.

Obstacles to Unification

The Dichotomy and Rivalry between Analysis and Intuition

Since antiquity, philosophers and scientists have distinguished between two principle forms of cognition, analysis and intuition. Analytical cognition commonly implies a step-by-step, largely conscious, logically defensible process of problem solving. Intuition ordinarily implies the achievement of an answer, judgment, decision, or idea by circumvention of such an explicit methodological cognitive effort. Analysis has always been more clearly understood than intuition because analytical cognition can be explained by what it signifies: a logical argument or mathematical model. Intuition, on the other hand, has remained mysterious, ineffable, and undefined, and perhaps for that reason has received only sporadic treatment in the research literature on cognition (but see the review by Royce, Coward, Egan, Kessel, & Mos, 1978; also Westcott, 1968). Researchers have, understandably, always capitalized on the analytical legacy of philosophy

(e.g., Mill's Canons, the syllogism, the probability calculus) and other normative models of cognition from which the movement of cognition could be observed. On the other hand, the parallel activity, construction of psychological models of successful intuition toward which cognition might be observed to move, has seldom been attempted, and there is no agreement that such models exist at present.

Analysis and intuition have traditionally been viewed as antithetical. This dichotomous relationship has led to a persistent rivalry between these modes of cognition (e.g., Berlin, 1978; Hanson, 1958; Pepper, 1948; Polanyi, 1958), and researchers have tended to argue in favor of one or the other. Some researchers have asserted that intuition is enormously beneficial because it has resulted in unconscious "leaps" to new discoveries, (for example, Holton, 1973; Wechsler, 1978; Royce et al., 1978; Westcott, 1968). But the preponderant view, as any one who reads through the judgment and decision literature of the 60s and 70s must conclude, is that intuition is inferior to analysis (see especially Slovic, Fischhoff, & Lichtenstein, 1977; Nisbett & Ross, 1980; Kahneman, Slovic, & Tversky, 1982). Intuition is hazardous, not only because it is "biased," but because persons are unwittingly overconfident in its accuracy. This negative view of intuition is the supposed fallibility of intuition led Slovic to state (1976) that "man may be an intellectual cripple." Recently Kahneman and Tversky indicate that although intuition may have its value they are uncertain as to what it might be: "Our problem is to retain what is useful and valid in intuitive judgment while correcting the errors and biases to which it is prone" (Tversky & Kahneman, 1982, p. 98). Although no suggestions are provided for what might be "useful and valid," they state that "The attempt to integrate the positive and negative accounts

[of intuitive cognition] is likely to enrich the theoretical analysis of inductive reasoning" (p. 507).

Asymmetrical research. In the research reviewed by Slovic et al. (1977), an analytical model is repeatedly employed as a standard against which intuitive cognition must compete; but no model of successful intuitive achievement against which analysis may be compared is offered. Indeed, researchers apparently ignore the fact that the criterion of "success" is entirely different for intuitive cognition than for analytical cognition. Intuitive cognition recognizes only empirical success--the functionalists' criterion--as the standard against which it should be evaluated. Intuition inherently scorns rationalism; intuition asserts that its value lies precisely in its ability to be empirically true despite its indifference to conformity with analytical methods: "I may not be able to explain it, but I know I'm right." It not only acknowledges that its answers will be different from those produced by analysis, it boasts that their value lies in that difference. Analytical cognition, on the other hand, accepts only the rationalists' criterion; truth must be derived from highly criticized, highly refined models, generally of a mathematical nature. Analysis confidently puts its faith in the coherence theory of truth, rather than the empirical or correspondence theory of truth which is the only criterion for the process of intuition.

Researchers who are themselves committed to the coherence theory of truth thus find that intuition fails; they observe that the process "violates" some normative process, and ignore the fact that "violating" normative processes is exactly what intuition wants to do; intuition is not embarrassed by rational failure. On the contrary; intuition celebrates such failure, provided success is achieved. But researchers committed to the coherence theory of truth

seldom offer their subjects the opportunity intuition prefers, namely the opportunity for empirical success in spite of rational failure. What circumstances might these be? In what circumstances might intuitive cognition empirically outperform analysis? Circumstances where analytical models display weak coherence, where there is disagreement among experts as to which models or processes are to be considered normative, where subjects are restricted in their analytical efforts to understand the problem.

A functionalist view would argue that intuition and analysis should be allowed to compete under similar ground rules, namely, in circumstances in which both types of cognitive processes are carried out by an organism, preferably a person since persons are the best known repositories of successful intuitive judgments and <u>both</u> types of criteria (normative and empirical) are employed. In a study which compared the empirical accuracy of both forms of cognition in the same persons (experienced highway engineers) coping with tasks in which the normative value of the analytical models varied from weak to strong, Hammond, et al. (1984) found that intuition and quasirational cognition often outperformed analysis in terms of empirical success.

<u>Failure to specify properties of intuition</u>. Without a clear identification of the properties of intuitive cognition, it is impossible to study the relative efficacy of intuition and analysis. For although the properties of analytical models can be made clear by their symbolic representations, unless the properties of intuition are specified with completeness (always the case with the properties of analytical models) it becomes a "garbage can" concept; any cognitive activity not specified as analytical is thrown into the intuitive category. It must be recognized that

subjects' expressions of uncertainty, confusion, embarrassment, ignorance and the like are not necessarily indicators of the presence of intuitive cognition; they may simply be what they are. Aside from conceptual weakness, open-ended specification of properties of intuition leads to a third difficulty, the impossibility of studying the middle range of cognition, quasirationality, to which elements of both intuition and analysis contribute, and within which the majority of judgments and decisions are carried out outside the laboratory.

The difficulties created by the overemphasis on analytical models in research on judgment and decision making have been recognized since the Slovic et al. (1977) review. Einhorn and Hogarth (1981), for example, state: "To consider human judgment as suboptimal without considering the limitations of optimal models is naive." Nevertheless, little has been done to redress this balance.

Arbitrary Choices of Task Conditions

Open-ended definitions of intuition have resulted in arbitrary choices by researchers of the set of task conditions that provide the best research site for studying judgment and decision making. Because such choices have been largely unique to each of the major approaches to research in judgment and decision making (see Hammond et al., 1980), a situation has been created in which the principles which putatively account for the organization of information are highly task-dependent. As a result, the name of the researcher is the best clue for guessing the organizing principle that will be discovered in any study. Currently, we may predict that Anderson (1974, 1981) will discover that cognitive organization is best described as an intuitive form of "cognitive algebra;" Edwards (1971), that some form of multiattribute

utility theory describes the organizing principle people intuitively apply; Tversky and Kahneman (1974, 1981), that people intuitively employ "heuristics" leading to the "biases and shortcomings" emphasized and generalized by Nisbett and Ross (1980). Keeney and Raiffa (1976) will indicate that the Subjective Expected Utility model is the organizing principle people should employ and will employ if aided to do so. Kelley (1973) will conclude that persons will employ intuitively the same organizing principle (factorial design) that scientists often employ and are thus "intuitive scientists" (but see Kelley, 1983, for a revision); Newell and Simon (1972), that people use "list structures" or "production rules" of "bounded rationality" as organizing principles. It is not surprising that the same investigator, reapplying the same method and procedure to similar formal task structures, rediscovers that his/her subjects are employing the same organizing principle found in previous studies carried out by them. Although Kahneman and Tversky do not put forward any theory of the organizational process (but see Einhorn, 1985; Birnbaum & Mellers, 1983, who do; see also Anderson, in press) they recognize the need for variation in choice of task conditions, thus: "We conclude that the conversational aspect of judgment studies deserves more careful consideration than it has received in past research, our own included" (1982, p. 504).

The theory put forward here argues that different task structures will induce different organizing principles, an argument empirically supported in Hammond et al. (1984; see Kelley, 1983, for a similar view). The theory has the significant advantage of encompassing much of the research in judgment and decision making. Indeed, if the different organizing principles discovered by different researchers do in fact account for behavior in different task circumstances, then we <u>may</u> have achieved cumulative results. Paradoxically, the persistence of investigators in using their favorite research tasks

establishes the reliability of findings within their restricted task conditions, thus perhaps providing the material for a cumulative discipline. The accumulation, within a theoretical framework, of reliable findings from a variety of tasks thus serves as a first step toward the goal of unification of research. Without such a framework, however, replication of findings with repeatedly employed task circumstances masquerades as generality.

Conventional Research Practices

Insufficient research is not an obstacle to a cumulative science--there are thousands of studies of judgment and decision making--rather, it is the nature of conventional research practices that prevents cumulation. The standard factorial design (between-group or within-group) that Brunswik (1952, 1956) called "systematic design" limits investigation to the examination of the effect of one, two, or three task conditions on judgment and decision making. Only a limited number of task conditions, or parameters of cognition, can be examined during any one experiment. Therefore, it is futile to attempt to estimate the relative importance of various task conditions independently employed in various studies, or to estimate the effect of their numerous interactions (a point emphasized by Cronbach, 1975), much less to attempt to aggregate the limited, piece-wise results produced by conventional studies into a theoretical framework. That is why students of cognition cannot now aggregate the effects of various task properties, estimate their relative importance, or determine how intuition and analysis are combined in any situation involving several task conditions.

Present research practice prevents the cumulation of results precisely because of the narrow research conditions that have become conventional ways to purchase rigor at the price of generality and cumulative science. Meehl (1978), not only finds twenty faults in conventional research practice, but ridicules current efforts to cumulate results:

> But, you may say, we do not look at just one [result]; we look at a batch of them. Yes, we do; and how do we usually do it? In the typical Psychological Bulletin article reviewing research on some theory, we see a table showing with asterisks ... whether this or that experimenter found a difference in the expected direction at the .05 (one asterisk), .01 (two asterisks!), or .001 (three asterisks!!) levels of significance. Typically, of course, some of them come out favorable and some of them come out unfavorable. What does the reviewer usually do? He goes through what is from the standpoint of the logician an almost meaningless exercise; to wit, he counts noses. If, say Fisbee's theory of the mind has a batting average of 7:3 on 10 significance tests in the table, he concludes that Fisbee's theory seems to be rather well supported, "although further research is needed to explain the discrepancies." This is scientifically a preposterous way to reason. It completely negates the crucial asymmetry between confirmation, which involves an inference in the formally invalid third figure of the implicative syllogism (this is why inductive inferences are ampliative and dangerous and why we can be objectively wrong even though we proceed correctly), and refutation, which is in the valid fourth figure, and which gives the modus tollens its privileged position in inductive

inference. Thus the adverse _t_ tests, seen properly, do Fisbee's theory far more damage than the favorable ones do it good.

> I am not making some nit-picking statistician's correction. I am saying that the whole business is so radically defective as to be scientifically almost pointless. (1978, pp. 822-823).

Meehl concludes that "the enterprise shows a disturbing absence of that _cumulative_ character that is so impressive in disciplines like astronomy, molecular biology, and genetics" (p. 807).

Nearly a decade ago, Olson (1976) identified specific obstacles to (a) aggregating task parameters into a theory as well as to (b) aggregating results into generalizations in connection with the "representative heuristic" after showing that the "bias" engendered by this "heuristic" could be negated by a slight change in task conditions, thus:

> The apparent violations of theory that are reported here can perhaps be attributed to previously incorrect specification of the essential [task] characteristics. Indeed, until a priori specification of the relevant features can be achieved, it is difficult to see how one would ever accumulate solid evidence against the theory: _Judgments that violate representativeness with respect ot one dimension are likely to confirm representativeness with respect to some other dimension_ [italics mine] (1976, pp. 607-608).

Hershey and Schoemaker (1980) and Phillips (1983) make similar observations with regard to related generalizations.

The complications arising from current research practice do not end with the easy upset of boldly offered generalizations. For when this happens, researchers conventionally attempt to prop the generalization up again by qualifying its validity. As the contingencies accumulate, the scope of the generalization, which evoked the initial interest, is lost. Hence the "decay" of generalizations (Cronbach, 1975), so aptly described by Meehl: "There is a period of enthusiasm about a new theory, a period of attempted application to several fact domains, a period of disillusionment as the negative data come in, a growing bafflement about inconsistent and unreplicable empirical results, multiple resort to ad hoc excuses, and then finally people just lose interest in the thing and pursue other endeavors" (1978, p. 807).

Meehl's (1978) call for drastic changes in research practice is, of course, not the first since systematic design practices were introduced. MacDougall was defeated in the early part of the 20th century when he challenged Wundt's demand for systematic design of experiments (Gillis & Schneider, 1966). Brunswik gained a foothold in 1943, however, with his detailed description of the advantages of experimental designs that represent the organism's ecology as well as organisms. That foothold widened as a result of his later experiments and subsequent treatises (1952, 1956; see Hammond & Wascoe, 1980, for recent examples of the representative design of experiments). In 1954, Hammond also argued that current research practices are more suited to the aims of applied research in agriculture than to those of basic research in psychology (see also Hammond, 1966; Hammond, Hamm, & Grassia, in press). And recently, Newell and Simon (1972, p. 13) made the same distinction; they indicate that their work "makes very little use of standard statistical apparatus.... our data analysis techniques resemble those of the bio-chemist or archaeologist more than those of the agricultural

experimenter." (See Simon, 1977, for a detailed methodological discussion.) And even the modern physical scientist is now finding that extrapolation from the laboratory to the "real world" brings its surprises. For example, Abelson (1985) indicates in an editorial in Science that physical scientists must recognize the advantages of representative over the systematic design of experiments when generalizing to ecological conditions:

> It has been known that SO_2, NO_x, and O_3 can have toxic effects on plants. In the early days, experiments tended to be performed "scientifically"; that is, plants were exposed in chambers in which the chemicals were tested one at a time. Under those circumstances, it was noted that concentrations of SO_2 and NO_2 greater than ambient were required to produce notable pathology. Indeed, low concentrations of NO_2 were sometimes beneficial (perhaps a fertilizer effect). However, in the real world, pollutants are present together. When experiments were conducted with ambient midday levels of ozone present (for example, 50 to 100 parts per billion), toxicity was noted. When the ozone was supplemented with NO_2, there was usually a substantial additional toxicity attributable to NO_2. Similar results were noted when ozone was supplemented with SO_2 (1985, p. 617).

Below we describe a methodology that (a) avoids the disadvantages of current research practices, (b) includes criteria from both the coherence and correspondence theories of truth, and (c) includes provisions for the analytical methods for aggregating results.

A Comprehensive View of Cognition

The theoretical framework presented here is intended to provide a basis for unifying these diverse efforts. It is based on four premises.

First, various modes or forms of cognition can be placed on a continuum that is marked by intuitive cognition at one pole and analytical cognition at the other.

Second, quasirationality, or "common sense," is the most common, and perhaps most powerful, form of cognition; it includes elements of both intuition and analysis.

Third, cognitive activities move along the intuitive-analytical continuum over time and alternate between the poles of this continuum. Successful cognition (by either analytical or empirical criteria) inhibits movement; failure stimulates it.

Fourth, the properties of cognitive tasks permit them to be ordered on the continuum according to their capacity to induce intuition, quasirationality and analysis.

A detailed treatment of the first four premises can be found in Hammond, 1980. Here I briefly discuss the first three premises and concentrate mainly on Premise 4.

Premise 1: Cognition Can Be Placed on A Continuum

The idea that cognition is a continuum demarcated by intuitive cognition at one pole and analytical cognition at the other is the basic premise of this theoretical framework. Shifting from the traditional idea that intuition and

analysis are dichotomous, "rival forms of knowing" (Berlin, 1978) to the idea of cognition as a continuum makes it possible to discern the various forms of cognition which different researchers have studied, to differentiate among them, and thus to develop a comprehensive view of cognition. (See Hammond et al., 1984, for an application of the theory.)

Premise 2: Quasirationality Is A Form of Cognition that Combines Elements of Intuition and Analysis

Rejection of a cognitive dichotomy in favor of a cognitive continuum also allows the concept of quasirationality to be developed. Quasirationality combines elements of both intuition and analysis, and thus occupies the middle range of the cognitive continuum; therefore it may well be the most common form of cognition. Brunswik (1956) used the concept of quasirationality to refer to a cognitive "compromise" between the intuitive and analytical poles of cognition. Just as conditions of illumination may pull the perception of any object toward retinal size and thus away from object size (or the reverse), so may task conditions pull cognitive activity toward intuition and away from analysis (or vice versa). As Brunswik put it, "In this light perception and the different varieties of thinking begin to reveal themselves as but different forms of imperfect reasoning, each with its own particular brands of virtues and 'stupidity,' if the term be permitted" (in Hammond, 1966, p. 491). In this way, Brunswik expresses the view that analytical cognition can not always and in every case automatically be considered to be the normative model for all cognition. For not only does perception reveal its "imperfect reasoning," but so do the "different varieties of thinking ... each with its own particular brands of virtues and 'stupidity'" (Brunswik, 1956). He illustrates this point by comparing perception with analytical

devices that take advantage of highly valid ecological cues, thus: "By contrast [with human perception], man-made gun or tank-stabilizers and the related 'thinking machines' may ... perform in a practically foolproof manner. This is due to the fact that they can usually be built with a concentration on a few cues of maximal trustworthiness and thus dispense with the services of cues of limited validity." That is, unaided perception can be abandoned in favor of analytical models when logic, mathematics, technology and science provide them. But in naturalistic circumstances, cognition that is unaided by these analytical advantages, or aided by an incomplete set of these, must depend on numerous cues of "limited trustworthiness," and is thus pulled toward the intuitive pole, therefore becoming quasirational, if not wholly intuitive.

Heider similarly emphasized the mediation of information via several cues of limited ecological validity (a Brunswikian concept now widespread and thoroughly corrupted; see Hammond, 1978, for examples). His terms "manifold of offshoots" (1926) and "event patterns" (1958, p. 35) refer to the multiple mediation of information. But Brunswik took a further step. Caught by Thorndike's use of the multiple regression equation to represent, or "model," quasirational cognition, he suggested that Thorndike's lead be followed. Brunswik uses the term "rational reconstruction," rather than "model," thus:

> In an attempt at rational reconstruction of the ways of the quasirational, with its reliance on [multiple] vicarious cues each of which is of limited validity, one may best refer to a remark of Thorndike [1918] comparing the impressionistic or intuitive judge of men to a device capable of performing what is known to statisticians as multiple correlation. (1952, p. 24).

By this analogy Brunswik introduced the theoretical basis for using multiple regression, which combines differently weighted variables under uncertainty, as a mathematical model for quasirational cognition (1956, p. 110). In the standard form of the multiple regression equation, the predicted event $Y = \sum b_i x_i$, where x_i refers to cue values and b_i to the weights attached to each cue. Additivity is therefore an explicit property of the organizing principle in this standard form of multiple regression. But since Brunswik emphasized the importance of the concept of compromise as an organizing principle in quasirational cognition, the additivity principle has therefore been converted to a weighted average principle in order to incorporate more completely the concept of compromise (and trade-offs) among cue weights (see Hammond, Stewart, Brehmer, & Steinmann, 1975; Hammond, 1981; also see Anderson, 1981, for extensive empirical support of the frequent appearance of weighted averaging "integration rules"). Thus, whatever shortcomings the multiple regression model may have as a descriptive device, its robustness makes it a strong candidate for veridicality on functional grounds (See Armelius, & Armelius, 1976; Brehmer, 1974; Einhorn, Kleinmuntz, & Kleinmuntz, 1979; Hammond, 1955, 1966, 1972, 1980; Hammond, et al., 1975; Hammond et al., 1984; Hogarth, 1981; Knowles, Hammond, Stewart, & Summers, 1972; Lindell & Stewart, 1974 regarding the mathematical and empirical representations.)

Thus, quasirational cognition is characterized by a dependence on numerous intersubstitutable cues of less-than-perfect ecological validity that are differentially weighted and organized into a judgment by means of a weighted average principle that can be represented or modeled by the multiple regression equation or similar representations (see, e.g., Anderson, 1981). When task conditions are arranged to reduce the number of cues and their

intersubstitutability, and to increase their ecological validity, and when an organizing principle is furnished by logic, mathematics, technology and science, cognition will be pulled from the middle ground to the analytical pole of the cognitive continuum. When the opposite occurs, cognition will move toward the intuitive pole.

The multiple regression equation (in either its additive or weighted average form) has become the normative (i.e., prescriptive) model against which quasirational cognition is compared. And the same form of a weighted average equation similar to a multiple regression equation is frequently employed as a descriptive model of quasirational cognition as well. Thus, for example, the accuracy of quasirational clinical judgments have been empirically compared with the accuracy of answers produced by the multiple regression equation ever since Sarbin (1942; see also Hammond, 1955; Hoffman, 1960: see Meehl, 1954 for an early review) as a model for describing quasirational cognition (see Hammond et al., 1984; Kirwan, Chaput de Saintonge, Joyce, & Currey, 1983a, 1983b, 1983c; Wigton, 1985, for recent studies in medical judgment).

One of the more compelling reasons for the use of a weighted average equation for modeling quasirational cognition is that it readily encompasses judgments that include cues and the relative importance of cues, both of which the person may be aware, as well as the functional relations between cues and judgments, and the aggregation principle, neither of which the person is likely to be aware. Thus, it exemplifies the combination of analytical and intuitive cognition.

On the other hand, in their discussion of the conjunction fallacy Tversky and Kahneman (1983) point out that their results cannot be encompassed by a simple form of a weighted average or weighted sum. But Einhorn (1985) and Birnbaum and Mellers (1983) show that different forms of a weighted average (e.g., the geometric mean) do provide a good account of these and other results. In doing so, both Einhorn (1985) and Birnbaum and Mellers (1983) preserve the "balancing" feature that is characteristic of all quasirational cognitive activity.

Quasirationality and Bounded Rationality

Newell and Simon (1972) have acknowledged Brunswik's influence on their work, and it is therefore not surprising that their term, "bounded rationality," shares common elements with Brunswik's concept of "quasirationality." March (1978) in particular presents a positive view of bounded rationality that is parallel to Brunswik's: "If behavior that apparently deviates from standard procedures of calculated rationality (e.g., Bayes Theorem) can be shown to be intelligent, then it can plausibly be argued that models of calculated rationality are deficient not only as descriptors of human behavior but also as guides to intelligent choice" (p. 573). Moreover: "goal ambiguity, like limited rationality, is not necessarily a fault in human choice to be corrected but often a form of intelligent choice to be refined by the technology of choice rather than ignored by it" (p. 598). Although March does not explain what he means by "intelligent choice," he apparently means empirical success, since he contrasts "intelligent choice" with "calculated rationality." Thus, whereas Newell and Simon argue that bounded rationality occurs because it must (i.e., human beings lack the competence to cope with ill-structured problems in a fully analytical manner), March follows Brunswik

in arguing that quasirationality may have empirical <u>advantages</u> over fully analytical behavior in certain circumstances.

March's assertions about the potential values of bounded rationality are not shared by current researchers in judgment and decision making, however. Despite some indications that departures from "calculated rationality" may be useful on certain occasions not clearly specified (see, for example, Fischhoff, 1982; Kahneman, et al., 1982; Tversky & Kahneman, 1981), no researcher in the field has claimed that bounded rationality may lead to <u>more</u> "intelligent" decisions than "calculated rationality," or suggested that certain heuristics should be used in place of calculated rationality where Bayes' Theorem, base rates, etc. may still be applied.

<u>Stimuli, Cues and Information</u>

In every judgment task, subjects are presented with some type of data, or information, which they are expected to use in order to make a judgment (or choice) with regard to some event, process, or data not presented to them. The terms <u>stimulus</u>, <u>cue</u> or <u>information</u> are frequently used to describe these materials. The term <u>stimulus</u> is, of course, a traditional one that stems from psychophysics; the term <u>cue</u> is taken largely from perception psychology that emphasizes the study of constancies, and the term <u>information</u> was introduced in the context of research on "information processing." Although all three terms have received wide usage, their conceptual status has seldom been distinguished, and are often used interchangeably. Hammond et al. (1975), did draw a conceptual distinction between the term <u>stimulus</u> and <u>cue</u>, but the distinction had no apparent effect on practice. Anderson et al. (1980) provide definitions for cue that illustrate the double usage: "a stimulus dimension; an aspect of an object or event to which an organism responds

(e.g., Restle, 1955; Bourne & Restle, 1959);" and "an aspect of proximal effects from an object or event to which an organism responds by making an inference about distal conditions" (p. 69). In their comment, Anderson et al. (1980) note that "'cue' in this second sense is contrasted with 'stimulus' which is conceived of as eliciting passive responses, rather than providing the basis for inferential activity" (p. 69).

It is clear that researchers who work mainly within the tradition of psychophysics, e.g., functional measurement (see Anderson, 1981), use the term "stimulus" almost exclusively to describe the materials presented to their subjects. Those researchers who work mainly within the framework of, say, the lens model use the term "cue" for the same purpose, despite differences in connotations. The distinction between being "stimulated" with, say, a sound of a certain frequency, that one is to somehow measure, and being presented with a cue to a distal object about which one is to infer something more than was presented, appears to be a distinction worth preserving. This distinction seems to have been employed early in the literature on cognitive psychology by Bruner (1957) in the title of his paper "Beyond the Information Given," presented at the 1955 Colorado Symposium. The term "cue" can be readily translated into "information" (e.g., the cue of linear perspective provides information about the distance of an object) and the reverse seems to be true also.

If the terms "cue" and "information" appear to emphasize or imply the process of inference more than does the term "stimulus," the appearance of the term "heuristic" in work of Kahneman and Tversky (Kahneman et al., 1982) moves even further in that direction. Indeed, the three heuristics mentioned most frequently, representativeness, availability and anchoring and adjustment,

appear to have been introduced to differentiate among different processes. But this is not clear. For if we consider only the concept of representations, it apparently was originally intended to be analogous to the concept of "cue," or at least to a descriptor or qualifier of a cue. Thus, for example, when introducing their work, Kahneman and Tversky state:

> The subjective assessment of probability resembles the subjective assessment of physical quantities such as distance or size. These judgments are all based on data of limited validity, which are processed according to heuristic rules. For example, the apparent distance of an object is determined in part by its clarity. The more sharply the object is seen, the closer it appears to be. This rule has some validity, because in any given scene the more distant objects are seen less sharply than nearer objects. However, the reliance on this rule leads to systematic errors in the estimation of distance. Specifically, distances are often overestimated when visibility is poor because the contours of objects are blurred. On the other hand, distances are often underestimated when visibility is good because the objects are seen sharply. Thus, the reliance on clarity as an indication of distance leads to common biases. Such biases are also found in the intuitive judgment of probability. This article describes three heuristics that are employed to assess probabilities and to predict values. Biases to which these heuristics lead are enumerated, and the applied and theoretical implications of these observations are discussed. (Tversky & Kahneman, 1974, p. 1124).

Later, however, a more differentiated view was presented, thus: "In summary, a relation of representations can be defined for (1) a value and a distribution, (2) an instance and a category, (3) a sample and a population, (4) an effect and a cause. In all four cases, representation expresses the degree of correspondence between X and M, but its determination is not the same in the four cases. In case (1), representativeness is dominated by perceived relative frequency as statistical association. In cases (2) and (3), representativeness is determined primarily by similarity, for example, of an instance to other instances, or of sample statistics to the corresponding parameters of the population. Finally, in case (4), [a judgment by] representativeness is controlled largely by (valid or invalid) causal beliefs" (Tversky & Kahneman, 1982, p. 87).

Thus, it appears that case (1) contains the original analogy to the cues of perception. That is, if a cue possesses a high ecological validity, then it should be highly representative. As early as 1967 Peterson and Beach (1967) reviewed many studies of subjects usages of cues of high and low ecological validity, both within the multiple cue probability learning paradigm where the ecological validity of a cue is compared with its utilization, as well as in many studies of subjective expected utility where the diagnostic value of a cue is compared with the subjective probability given by a person. In cases (2) and (3) Kahneman and Tversky indicate that representativeness refers to judgments determined by the similarity of the instances presented to the instance to be inferred. Similarity is determined by "feature matching" (Tversky, 1977; Tversky & Gati, 1982) in which differential weighting of feature matches may occur. "Similarity" provides a case of counting the number of features matched, rather than measuring the relative frequency of occasions in which (proximal) cue values are associated

with criterion, or distal object, values. Nevertheless, the concept of cue might well be retained for representativeness, if we assume that "similarity" describes or qualifies the relation between what is given and what is to be inferred. Case (4), however, is clearly different from cases (1), (2), and (3), for it directly refers to "causal beliefs," a matter to which the concept of cue bears little relation.

In summary, the concepts of stimulus, cue and heuristic appear to be parts of different theoretical vocabularies. To what extent they can be used interchangeably is uncertain. A stimulus does not seem to be a heuristic, although a stimulus may be a cue. A cue may be a stimulus, and a cue may serve as a heuristic. A heuristic may well serve the same function as a cue, and may even serve as a stimulus. Classification of the references of these terms would serve all researchers well, if only it results in making it easier to compare results of studies carried out with different frameworks.

A Comprehensive View of Cognition

The first premise, that cognition is best represented by a continuum rather than a dichotomy, is the foundation for the second premise that elements of both intuition and analysis frequently combine to provide a form of cognition described as quasirationality. Together these premises offer a comprehensive theory of cognition that encompasses a variety of cognitive activities. Such activities may be congruent with, or match, task conditions, or they may be misapplied. For example, research reviewed in Slovic et al. (1977) and Kahneman et al. (1982) stresses the "shortcomings and distortions" as well as the biases which occur when intuition is applied to problems amenable to analytical solution. In contrast, the comprehensive view recognizes that analysis as well as intuition or quasirationality may be

misapplied. Thus, all forms of cognition make special contributions to accuracy and error, and none can be considered the normative model for all others independently of task conditions.

Premise 3: The Effect of Time

Cognitive activities move along the intuitive-analytical continuum over time and alternate between locations on the continuum; therefore, the relative contributions of intuition and analysis to a person's judgments change over time.

The alternation between intuition and analysis has been frequently reported in the history of science (see, for example, Cohen, 1985). It is dramatically illustrated in Figure 1, taken from Charles Darwin's notebooks (see Gruber, 1974, 1980; also in Wechsler, 1978). Here Darwin's pictorial image of the tree of evolution is represented in "The Tree of Life" diagram and his notes that represent his attempts at verbal analysis of this image are contained on the very same page. As Gruber noted, it took Darwin fifteen months after this pictorial metaphor was formed to arrive at a satisfactory verbal, analytical representation of the idea contained in the metaphor. If Darwin's pictorial metaphor suggests that he started to construct his theory of the tree of life from the intuitive side, Galileo may be said to have started from the analytical side. Yet Galileo's analytically deduced experiments have been demonstrated to have contained much that is intuitive (see Clavelin, 1974, pp. 430-431). Clavelin notes that doubts have been expressed that the results from Galileo's experiment using the inclined plane could be produced by his crude apparatus, thus suggesting that the achievement of his results was assisted by intuitive or quasirational cognition.

Insert Figure 1 about here

The movement of cognitive activity along the intuitive-analytical continuum over time has been described by several philosophers. For example, Polanyi commented on the mathematician's alternation between the poles of the cognitive continuum:

> The manner in which the mathematician works his way towards discovery, by shifting his confidence from intuition to computation and back again from computation to intuition, while never releasing his hold on either of the two, represents in miniature the whole range of operations by which articulation disciplines and expands the reasoning powers of man. (1958, p. 131)

Pepper, however, was most explicit about the "tension" created by the use of different forms of knowing that leads to alternation on the cognitive continuum:

> This tension between common sense and expert knowledge, between cognitive security without responsibility and cognitive responsibility without full security, is the interior dynamics of the knowledge situation. The indefiniteness of much detail in common sense, its contradictions, its lack of established grounds, drive thought to seek definiteness, consistency, and reasons. Thought finds these in the criticized and refined knowledge of mathematics, science, and philosophy, only to discover that these tend to thin out into arbitrary definitions, pointer readings, and tentative hypotheses. Astounded at the thinness and hollowness of

> these culminating achievements of conscientiously responsible cognition, thought seeks matter for its definitions, significance for its pointer readings, and support for its wobbling hypotheses. Responsible cognition finds itself insecure as a result of the very earnestness of its virtues. But where shall it turn? It does, in fact, turn back to common sense, that indefinite and irresponsible source which it so lately scorned. But it does so, generally, with a bad grace. After filling its empty definitions and pointer readings and hypotheses with meanings out of the rich confusion of common sense, it generally turns its head away, shuts its eyes to what it has been doing, and affirms dogmatically the self-evidence and certainty of the common-sense significance it has drawn into its concepts. Then it pretends to be securely based on self-evident principles or indubitable facts.... Thus the circle is completed. Common sense continually demands the responsible criticism of refined knowledge, and refined knowledge sooner or later requires the security of common-sense support. (Pepper, 1948, pp. 22-23)

Pepper then asks: "Why cannot the two merge?"

But Hanson (1958) argued that they <u>must</u> merge: "the steps between visual pictures and statements of what is seen are many and intricate [cf. Darwin's pictorial metaphor and subsequent verbal and mathematical efforts]. Our visual consciousness is dominated by pictures; scientific knowledge is primarily linguistic.... Only by showing how picturing and speaking are different can one suggest how [they] may [be brought] together; and brought together they must be" (p. 25).

The remarks of Polanyi, Pepper, and Hanson offer a challenge to judgment and decision researchers and cognitive psychologists in general. For example: Does alternation in fact occur? What factors influence it? What are the consequences for achievement? Does a faster or slower rate of alteration aid achievement? Is Hanson correct when he implies that intuition and analysis "must" be "brought together" for cognitive activity to be at its best? And is Hanson concurring with the view expressed by March and Brunswik that quasirationality is the most effective form of reasoning in some circumstances?

These questions can be brought to bear on issues regarding cognitive activity in problem-solving tasks. Consider a subject attempting to employ an analytical strategy in a highly analytical task such as the Tower of Hanoi exercise, in which a definite answer is being sought. When the first efforts at analysis fail, the subject's cognitive activity moves away from analysis to quasirationality; that is, the subject's cognitive activity begins to acquire elements of intuitive cognition as indicated in Tables 1-3 (see Jeffries, Polson, Razran, & Atwood, 1977, for an example). If the problem is so difficult that analysis fails to provide a solution, then the subject's cognitive activity may move far enough along the cognitive continuum to become predominantly intuitive. At this point cognition may consist almost entirely of pictorial imagery, as in Darwin's case (but seldom if ever allowed or recorded in studies of problem solving). If intuitive activity provides an idea which the subject wishes to test, the subject may be said to move from intuition through quasirationality to the context of analysis; or as Bronowski (1978) put it, to move "from metaphor to algorithm." Hamm (1985) has taken preliminary steps toward testing Pepper's description of cognitive activity, and, using the definitions of analytical and intuitive cognition derived from

cognitive continuum theory, found support for the alternation hypothesis in examination of the cognitive activity of six expert highway engineers, a physician, and a medical student.

Premise 4: Cognitive Tasks May Be Ordered on A Continuum According to Their Capacity to Induce Elements of Intuitive and Analytical Cognition

It is this premise that provides the possibility of studying intuition, for it requires specification of (a) the task properties that are predicted to induce intuition or analysis, (b) the cognitive activities defined as intuitive and analytical that are predicted to follow from specified task properties, and (c) the judgment and decision behaviors predicted to follow from specified task properties and specified cognition activities. Intuition and analysis are thus treated as intervening variables that are anchored in task conditions and behavioral consequences.

The foundation of the premise is Tolman and Brunswik's (1935) assertion that a theory of cognition should be based on the characteristics, or "causal texture," of the task environment. Although in 1955 Brunswik (1957) and Simon (1956) subsequently issued programmatic statements to support this assertion, little progress has been made beyond restatements of the need for analyzing the range of task conditions. (For a restatement for the field of judgment and decision research see Wallsten, 1980, p. 220).

The necessary relationships are displayed in Tables 1, 2, and 3. Only the most important predictions are traced out and explained below.

Insert Tables 1, 2, and 3 about here

Task properties are grouped into three main categories: (a) complexity of task structure, (b) ambiguity of task content, and (c) form of task presentation.

Complexity of Task Structure: Single-System Case

The complexity of the space that separates proximal, often palpable cues from the distal, often impalpable variable to be inferred from them can be described in several ways. Distal-proximal separation is shallow; that is, has fewer nodes or connections, when causal texture is at a minimum, as in the question: "Was this poker chip drawn from this bag or that one?" Distal-proximal separation is deep when the subject must work through hierarchies of interdependent causal variables, or an intricate causal network of nodes and connections. Artifactual tasks are often deliberately constructed to shorten and simplify the complexities of deep distal-proximal separation that naturalistic tasks ordinarily present.

The formal properties of the region between the readily observable proximal data and the distal data to be inferred, determine the complexity of the causal texture of the task. In the single-system case (no criterion available), the parameters of this region that can be manipulated by the researcher include (a) the articulation of the judgment scale employed, (b) the number of cues presented for each judgment, (c) contemporaneous versus sequential presentation of cues, (d) the degree of vicarious mediation (intra-ecological correlation) among cues, and (e) cue distribution characteristics. Each is discussed in turn.

The articulation of the judgment scale. "Articulation" refers to (a) the number of alternatives a person must consider, and (b) the number of steps, branching points (alternative paths between cues presented and the distal variable) to solution. Both of these features have varied widely in judgment and decision research questions. Compare, for example, the dichotomous scales frequently used in studies of choice (see Slovic et al., 1977) with the continuous scales typically used in studies of judgment by Anderson (1981) and Brehmer (1980) (see also the review by Einhorn and Hogarth, 1981). Or contrast the successive revision of probabilities on the basis of new information with work on multiple cue probability learning in which a single, never-revised judgment is made in response to the same set of cues in a large number of trials (discussed in Hammond et al., 1980).

The number of cues presented for each judgment. Cues are generally identified by the researcher as palpable (proximal) potential sources of information about an impalpable (distal) variable. Hierarchies of cue organization may be created when single cues are "chunked" into patterns that in turn serve as cues. Such "chunking" occurs when an organizing principle is present in the subject's cognitive system.

A cue is termed "ambiguous" when it results in judgments that fall below some functionally determined criterion of reliability. In general, the _ambiguity_ of a cue can be described or measured in terms of its "ecological reliability" (as distinguished from _ecological validity_; cf. Brunswik, 1956, pp. 30, 35, 37, 38; see Edwards, John, & von Winterfeldt, 1981, for a separation of ecological reliability and validity ("diagnosticity") by assigned function in a two-person situation).

Contemporaneous versus sequential presentation of cues. When cues are displayed contemporaneously, the values of the cues, but not their number, are successively changed. For example, a subject may be asked to judge another person's character from a photograph that displays all the physiognomic cues present in a face. After that judgment is made, a new photograph is presented and a judgment for the second face is made without explicit reference to the first. Although the values of the several cues may change (e.g., more or fewer wrinkles in the faces), the number of potential cues does not change over trials.

In other studies, tasks may present the subject with part of the pertinent information on one trial and new information on new dimensions or cues on sequential trials, thus providing choice points for judgments as the new cues (or new cue values) are sequentially encountered. "Roving" back and forth across previous and potential future choices is characteristic of behavior induced by the tasks employed in problem solving research. Pennington and Hastie (1981) make explicit use of this distinction in their review of juror decision making. (See also Ward & Jenkins, 1965.)

Vicarious mediation (intersubstitutability, redundancy) of cues. Vicarious mediation refers to the intersubstitutability of cues in the environment (see Brunswik's and Heider's comments above). When cues are continuous, a common form of the measurement of vicarious mediation is the co-occurrence, or intercorrelation, or intra-ecological correlation, among cues. When cues are dichotomous, the relative frequency or the (conditional) probability of co-occurrence may be used as measures of redundancy. Large numbers of co-occurring, redundant, and thus intersubstitutable, perceptual cues are apt to be found in naturalistic tasks. As cognitive task conditions

become increasingly artifactual, the naturalistic form of vicarious mediation is generally eliminated from the task because intersubstitutability often provides redundant and perhaps expensive information. Where certainty of inference is essential and can be afforded (as in airplanes or spacecraft), vicarious mediation is demanded and provided. In research environments, however, cognitive tasks are often constructed without regard to vicarious mediation of either type, and thus overgeneralization occurs.

There is an important distinction between the vicarious mediation that appears in naturalistic tasks and the redundancy built into artifactual tasks. Naturalistic vicarious mediation can be called "horizontal" because it often involves the covariation among cues presented contemporaneously (co-occurrence). On the other hand, artifactual redundancy (or "reliability") can be called "vertical," because it involves the sequential presentation of cues that are considered only if needed. (For example, if this instrument fails, then call up and read one that provides the same information.) In the former case, co-occurrence may provide cues that are either correlated with the criterion and with one another or independent of one another. Thus, various species may take advantage of horizontal redundancy of the latter kind in nature. For example, homing pigeons rely on the sun for orientation, but during cloudy weather they rely on the earth's magnetic field (Gould, 1980; see also Johnstone, 1981, for similar examples).

The implicit distinction between horizontal vicarious mediation and vertical redundancy can be seen in various approaches to judgment and decision research. For example, Information Integration Theory (Anderson, 1981) and Social Judgment Theory (Hammond et al., 1975) typically display a comparatively wide array of information (several cues) contemporaneously, thus

providing the possibility for horizontal vicarious mediation. On the other hand, Psychological Decision Theory and Behavioral Decision Theory (see Hammond et al., 1980; Anderson et al., 1981) tend to display information from a smaller set of cues sequentially, thus providing the possibility for vertical redundancy.

New approaches to judgment and decision making that tackle the problem of studying cognition in dynamic decision tasks (Brehmer, 1985; Kleinmuntz, 1985; a research effort called for by Hogarth, 1981) must consider both types of vicarious mediation.

Cue distribution characteristics. The usual statistical considerations (variation, kurtosis, skewness, etc.) apply here. The effects of these task characteristics are seldom examined in judgment and decision research, despite the results of early work indicating their importance (see Slovic & Lichtenstein, 1971).

Complexity of Task Structure: Double-System Case

In the double-system case either or both of the following is true: (a) the subject observes an outcome; (b) the researcher knows the outcome from either empirical observation or application of a rational model such as Bayes' Theorem, may or may not present that outcome to the subject. The following parameters should be considered in the double-system case: (a) the shape of the functional relation (i.e., the function form) between each cue and the outcome, (b) the ecological validity (see Hammond, 1978, for a description of recent extravagant abuses of this term) between each cue and the outcome, (c) other statistical characteristics such as variation, shape of the distribution, etc., (d) the nature of the organizing principle that

encompasses the relation between cues and outcomes (e.g., Bayes's Theorem, a regression equation, a physical law or an arbitrary rule as in concept formation tasks; see Hammond, 1981, for a discussion of organizing principles), and (e) the relation between depth and surface characteristics of tasks.

Predictions. The task properties indicated on the left of Table 1 will induce in the single-system (no outcome) case the cognitive properties indicated on the left in Table 2; see Table 3 for predictions for the double-system case.

Explanation of the predicted relation between complexity of task structure and cognitive properties in the single- and double-system cases. A task that provides a highly textured judgment scale with many gradations and that requires a judgment regarding a spatially or temporally remote state of affairs based on the contemporaneous display of a large number of cues, the values of which the subject must estimate without assistance, will induce the properties of intuitive cognition. This is particularly true when there is horizontal vicarious mediation (positive correlations among the normally distributed cues) for which the weights are approximately equal, and when a linear organizing principle will frequently provide approximately correct answers.

If the subject is ignorant of the causal texture between cues and the distal variable to be judged under the above conditions, the results will be as follows: (a) Low cognitive control will be induced because irreducible ignorance means irreducible uncertainty about what leads to what. (b) Unconscious data processing will occur because the subject lacks an applicable organizing principle. (c) Vicarious functioning will occur because the

presence of many contemporaneously displayed interdependent cues to be measured concurrently by the subject encourages shifting cue utilization. (d) Rapid data processing will occur because no organizing principle is available that would require or allow sequential analysis of the contemporaneously displayed data throughout the deep causal network of entangled relations; that is, time cannot be used. Raw data or events will be stored in memory and recalled by common associative elements rather than by conceptual relations because of the absence of a conceptual scheme. (e) Pictorial metaphors will frequently be employed because these provide the only means of conceptual organization. (f) If a stable judgment policy is somehow established, it will be resistant to change because new information can readily become a part of a diffuse cognitive system without directly contradicting any part of it.

On the other hand, if the judgment scale provides only a dichotomy, and if the inference is to a more proximal than remote state of affairs, and based on a few cues that can be sequentially analyzed, then the information readily lends itself to organization by means of an explicit, if-then principle; and therefore, cognitive control and reportability will be enhanced. Nonlinear principles are more apt to be used in these circumstances. For example, two cues can be multiplied or used in a synergistic fashion, but not five or six unless they are presented sequentially. The low redundancy of information will also enhance the use of nonlinear organizing principles. The use of explicit, nonlinear organizing principles slows data processing and allows complex conceptual relations rather than specific events or associative elements to be stored in memory. Thus, verbal or quantitative metaphors can serve as reportable organizing principles and hypotheses to be tested. Because of the analytical nature of nonlinear organizing principles, weights

will not appear in them. Cognitive weighting, for example, does not appear in highly analytical statements, such as physical laws.

Ambiguity of Task Content

Several parameters define the subjective ambiguity of task content; that is, the degree of understanding a subject believes s/he has regarding the task material. In the single-system case the most important of these is whether the subject brings to the task a conscious awareness of an organizing principle that permits the information to be used in what the subject believes will be an effective way. If (a) the subject does not bring such a principle, or (b) no empirical or logically deducible outcome exists by which the subject's judgment or decision can be compared, or (c) there is no prior familiarity with the task content, of (d) little or no information is given to the subject about the task at the time the subject first encounters it (feed-forward), ambiguity is at a maximum. Such tasks are very often employed in research. In the double-system case in which feedback is provided to the subject and, therefore, in which learning is possible in principle, additional parameters that must be considered include: (e) type of feedback, and (f) the degree of accurate prediction or judgment possible. Each is discussed in turn.

Organizing principles. The process of organizing information into a judgment or answer has been the primary focus of cognitive psychologists. The fact that researchers have chosen different research sites on the cognitive continuum has affected the manner in which subjects bring organizing principles to bear on research tasks. For example, tasks used by Anderson (1974, 1981) offer no opportunity for the subject to apply a consciously developed principle of which s/he is highly aware. Brehmer and his colleagues, on the other hand, often train their subjects to develop an

organizing principle, but do so in a manner that leaves the subject unaware of what the principle is. This is particularly true of their studies of interpersonal conflict and interpersonal learning (see especially, Brehmer, 1976). Other researchers (e.g., Tversky & Kahneman, 1974, 1981) seek to discover which heuristic (cue?) the subject will use when s/he is not cognizant of the logically correct analytical organizing principle (e.g., Bayes' Theorem) to be applied. Still others, primarily in the field of social perception (see Harvey, Ickes, & Kidd, 1976), try to find the organizing principle that subjects employ when circumstances do not make clear to either the subject or the researcher what the correct organizing principle is, or when the existence of such a principle is doubtful because of the absence of a substantive theory concerning the social perception involved. Dawes (1979) has emphasized the utility of a simple linear additive organizing principle in social judgments, an argument put forward earlier by Hammond (1955), Hoffman (1960), Hammond, Hursch and Todd (1964) and Hammond et al. (1975).

Existence of task outcomes. If the form of the task does not include an empirical or logically determined outcome, the subject may engage in a wide range of cognitive activities. But the presence of a task outcome that will permit empirical or logical evaluation of the subject's cognitive effort focuses cognitive activity. Thus, for example, answers to problems for which Bayes' Theorem provides a logical outcome are restrained by task outcomes, whereas value judgments are not. Additionally, it is important to distinguish between those judgment tasks in which the subject acts to affect the outcome and those in which no task-relevant action takes place. For as Einhorn and Hogarth (1978) have shown, actions that affect the observed outcome can and may make learning impossible. (See Hammond, 1980, for a comment on evolutionary epistemology that parallels this observation.)

Prior familiarity with task content. The degree of the subject's familiarity with task content will affect the likelihood that s/he will apply various organizing principles, including the various heuristics from expert and common knowledge. Larkin, McDermott, Simon, and Simon (1980) not only show the relevance of the well-known work of DeGroot (who showed the difference in chunking between chess experts and novices), but also differentiate the semantics of task content from its syntax and indicate that different cognitive activity may follow from the subject's differential familiarity with each.

Feedforward. There are both overt and covert means for indicating to subjects how they should approach their task. Researchers may publish careful descriptions of the instructions they give their subjects, but fail to specify the implications of the instructions. When this occurs, the amount of control the subject was expected to exercise over his/her cognitive activity cannot be determined. Do the instructions or the task materials imply that the subject should already possess an organizing principle that will permit analytical cognitive activity? Or do the instructions imply that little is expected other than (unpenalized) guessing? Does the time allocated imply that the subject is expected to find or create an organizing principle, or to proceed without one? Some researchers provide no prior information regarding the task for their subjects while others on occasion train their subjects in an effort to establish, and thus study, the effects of new information on cognitive systems with specified values for certain parameters (see Brehmer & Hammond, 1977; Hammond et al., 1975 for examples).

Feedback. The strong tradition of identifying outcomes as reinforcers, and the emphasis on the role of reinforcement in learning, have hindered researchers in cognition from breaking with this singular, undifferentiated concept of feedback. "Knowledge of results" has long been accepted as the *only* type of feedback a researcher might conceivably apply when investigating learning. But, as indicated by Hammond et al. (1964; see also Hammond, 1971), in judgment tasks involving cues of limited ecological validity, there are at least 50 combinations of feedback that can be provided to the subject regarding the structure of the task. In particular, when the information value of outcomes is weakened by an uncertain relation between cues and outcomes, then information about task structure (e.g., ecological validities of cues, task function-forms, etc.) is more informative, and thus more likely to enhance learning than outcomes (Hammond, 1971; Deane, Hammond, & Summers, 1972; Lindell & Stewart, 1974; Mumpower & Hammond, 1974; Wigton, 1985; see also Gillis, Stewart, & Gritz, 1975, in which information about task structure is shown to enhance learning even in psychotic patients). Indeed, Hammond, Summers, and Deane (1973) have shown that outcome feedback can be *detrimental* to learning in multiple cue probability learning tasks. (See Howson, 1979; Hoffman, Earle, & Slovic, 1981, for recent confirmation of these results.) Adelman (1981, p. 423) showed that "the relative effectiveness of outcome and cognitive feedback depends on formal, substantive and contextual task properties," thus demonstrating once more the need for carefully specifying task conditions in order to justify one's generalizations.

Degree of accurate prediction possible. The accuracy of prediction or judgment that is possible is always limited by the statistical uncertainty of the task (see Hursch, Hammond, & Hursch, 1964; Tucker, 1964 for descriptions of such limits for various task conditions). Specification of such limits is

necessary if performance is to be evaluated (see Szucko & Kleinmuntz, 1981, for a recent example in relation to judgments of polygraph data).

Predictions. Task properties on the left (right) in Table 1 induce those cognitive properties on the left (right) in Table 2, with the behavioral consequences indicated on the left (right) in Table 3.

Explanation of the predicted relations between ambiguity of task content and cognitive properties. A task will induce the properties of intuition when (a) the subject is not aware of a readily available organizing principle; (b) no task outcome (criterion) is available by which a judgment can be evaluated; (c) the subject is unfamiliar with the task; (d) the subject receives no training or information; (e) feedback is, in principle, not helpful; and (f) the degree of accurate prediction is low. As Tables 1-3 indicate, opposite task conditions induce analytical cognition.

If the subject is unaware of a readily available organizing principle a weighted average procedure will be employed, as Anderson (1981) has often empirically demonstrated. The basis for this prediction is the robust, and thus successful, character of this organizing principle. In particular, it can yield approximately correct answers (and only approximations can be achieved in tasks of this sort) despite incorrect weights, incorrect function forms and the incorrectness of the principle itself (see Dawes, 1979; Dawes & Corrigan, 1974). Such a powerful organizing principle would provide considerable survival value in ambiguous task circumstances. Further, such robustness makes learning unnecessary under precisely those conditions in which learning is difficult to achieve. (See Hammond, 1980, for further treatment of the survival value of the weighted averaging method of aggregating information.) As the ambiguity of task conditions decreases,

however, quasirational mechanisms, such as various heuristics suggested by Thorngate (1980) and by Newell and Simon (1972) will serve as organizing principles. Such heuristics are invented or constructed by appeal to ideas that are at least partially defensible on experiential grounds. Subjects untutored in the logic of the statistical method can and do offer a quasirational defense of the use of such heuristics. However, when an appropriate organizing principle is available, the subject will not find it necessary to employ quasirational heuristics, but will become an analytical problem solver. Indeed, if sufficient time and incentive exist, they may rediscover wholly defensible organizing principles or logical solutions, as indicated above.

Lack of a task outcome induces intuitive cognition because of the resultant inability to evaluate or criticize the judgment or decision offered. And lack of familiarity with task content induces intuition because of the lack of an organizing principle to cope with it.

Even experts may unwittingly organize information by means of a linear (weighted average) model if familiar material is presented in an unfamiliar way and they are thus unable to apply familiar cognitive algorithms, or theories, for organizing the data. For example, scientists are often at a loss when required to make judgments about the risk of environmental intrusions because of the problem of generalizing results from controlled to uncontrolled conditions outside the laboratory (for examples, see Adelman, Deane, & Hammond, 1976; Hammond, Anderson, Sutherland, & Marvin, 1984; Hammond et al., 1984).

If feedforward in the form of training or prior instruction is provided with regard to the parameters of the task, then cognition will be shifted toward the analytical pole, and learning will be enhanced according to the nature of the feedback that is provided. If feedback is limited to outcomes in probabilistic tasks, performance may be degraded rather than improved (as indicated above). Outcome feedback generally enhances performance in analytical, fully determined tasks, of course; but cognitive feedback, that is, feedback that provides full information about the discrepancy between task parameters and the subject's performance, is more likely to enhance performance in any case (Adelman, 1981; Hammond, 1971; Hammond & Summers, 1972; Hammond et al., 1975; Hoffman et al., 1981). "Full information" implies that the subject is provided with the correct organizing principle for the task as well as correct information about other task parameters. Irreducible task uncertainty that results in the inability to achieve perfect performance is highly conducive to the use of intuitive cognition because analysis is frequently defeated (see especially Hoffman et al., 1981).

Form of Task Presentation

Slovic and Lichtenstein (1971) and Hammond et al. (1980) discussed the tendency of researchers to employ only the form of task presentation which they or their teachers have invented and to reject the wide variety of forms developed by others. Larkin et al. (1980) illustrate this tendency. They assert: "Expertness probably has much the same foundations wherever encountered. As in genetics, we learn much about all organisms by studying a few intensively. Chess, algebra, and physics are serving as the *Drosophila, Neuropora* and *Escherichia coli* of research on human cognitive skills" (p. 1336). The suggestion that the cognitive operations demanded by chess,

algebra, and physics exhaust the concept of expertness of "cognitive skill" provides yet another painful example of gratuitously generalizing the results obtained with one form of problem and one method of analysis. Instructive and informative as the results obtained by verbal protocol analysis in relation to problem-solving may be, such methodological generalization will seem unwarranted to the researchers who find problems other than "chess, algebra or physics" to be plausible, if not requisite, sites for studying cognition. Consideration must be given to the variation in the form or structure of tasks, not to mention variations in task complexity and ambiguity described above.

Simon, one of Larkin's collaborators, argued differently in 1969 that it is the structure of the environment that selects the behavior: "The apparent complexity of [man's] behavior ... is largely a reflection of the environment in which he finds himself (p. 25). And in 1975 Simon asserted that

> Discovery of what subjects learn can be approached experimentally but important preliminary insights can be gained by analyzing the structure of the task itself to determine the possible alternative ways of performing it.... [and] a formal analysis of the environment can help define the differences in the demands that different methods of task performance place upon the subject. (p. 268; see also Simon & Reed, 1976)

This suggests that variations in the complexity of the task lead to variations in behavior. Therefore, it is incumbent upon researchers to specify the relation between differences in the form or structure of the task and related differences in cognitive activity, in contrast to "learning much about all ... by studying a few."

Specific variations in the form in which tasks are presented to subjects include (a) type of task decomposition, (b) type of cue data and judgment required, (c) type of cue definition, (d) response time permitted or implied, and (e) type of feedforward.

Task (and cognitive) decomposition. One form of task decomposition is a priori; that is, the researcher identifies the parts of the task (e.g., probabilities and utilities, diagnostic information and base rates, or means and ends) for the subject before the subjects exercise their judgment.

A second form (often called "wholistic") occurs when natural circumstances, or photographs of them (see, for example, Shanteau & Phelps, 1977) or actual persons or places, or schematic representations of these (see for example Brehmer & Kuylenstierna, 1978) provide the task materials. Such task decomposition is a posteriori if identification of parts of the task for the subject occurs after the subject has performed whatever the task demands.

Linked closely to a priori and a posteriori decomposition of the task is the a priori and a posteriori decomposition of cognitive activity. For example, when the experimenter instructs the subject that s/he is expected to think about the problem in terms of the probabilities and (possibly) utilities associated with various choices, the experimenter decomposes the subject's cognitive process in the same way. The researcher may then exhibit the obtained decomposed process (in the form of a decision tree or similar) for the subject's inspection. In this way, the subject's cognitive activity regarding the task is decomposed into its elements (probabilities and utilities) prior to the subject's overall choice in connection with an a priori decomposed task.

A posteriori decomposition of the subject's cognitive activity, on the other hand, occurs in connection with wholistic displays of information. After sequential displays of numerous cues, then the researcher/analyst decomposes the cognitive activity of the subject into its constituent parts--weights, function forms, organizing principles. (See Hammond et al., 1980, for details concerning the variety of techniques employed in decomposition.)

Data-driven versus memory-driven judgments. Hastie and Park (in press) provide a useful distinction between (a) judgments that must rely on the present data for the subjects have little or no experience and thus cannot rely on memory, and (b) judgments that must rely entirely on memory rather than currently displayed data. Drawing this distinction enables them to find some fifty different studies of this topic, as well as five putative models of the relation between these two forms of judgment tasks. All five models appear to be "bias" models; none purport to account for accuracy of judgments that are either data-driven or memory-driven. Thus, all five seek to explain departure from analytically correct judgments.

Type of cue data and judgment required. Researchers present data to subjects in forms that range from continuous cues indicated by line drawings and bar graphs to geometric figures, schematic faces, photographs, adjectives, and verbal descriptions. Judgment scales also vary widely and include continuous ratings, rankings, and choices and requests for probabilities. (See Slovic & Lichtenstein, 1971, Rappoport & Summers, 1973, Slovic et al., 1977, Hammond et al., 1980, Einhorn & Hogarth, 1981, for examples.) One of the more dramatic, counter intuitive illustrations of the differential effects of the form of cue display is provided by Stock and Watson (1984). They

report that even accountants with "higher levels of training" made more accurate judgments regarding bond ratings when their judgments were based on schematic faces used to represent numerical data then when their judgments were based on the numerical data themselves.

Type of cue definition. Of particular importance is the question whether it is the subject or the researcher who measures the information provided. For example, in a study of physiognomic perception the subject must measure perceptually the number of wrinkles in the photograph of a face, or the textural gradient in a scenic display. But in many cases the various levels or quantities of cues are measured by the researcher and then presented to the subject in quantitative form. Perceptual ambiguity is entirely eliminated. Seldom is this distinction drawn when studies are described or compared. (Cf. Stock & Watson, 1984, and Anderson, 1981.)

Response time permitted or implied. Problem solving researchers often record judgment times because (a) time-to-solution is often presumed to be a dependent variable in the experiment, and (b) they believe that there may be wide individual differences in time taken to reach a solution. The extent to which short or long response time is encouraged in judgment and decision research, however, often can only be guessed at by a reader attempting to replicate the experiment. In the vast majority of judgment tasks subjects infer that they are not expected to take more than 15-45 seconds to reach a judgment, and, in all likelihood, they seldom do. For example, if a judgment task is described to a subject, and the subject is then shown a stack of 400 cards, and if the subject knows that s/he has 50 or 100 minutes in which to judge them, a brief response time will have been implicitly but strongly encouraged. Yet the very same task might be given under conditions in which a

long response time is implicitly encouraged: the subject might be required to judge 20 profile-cards per day for 20 days. Although variations in time are seldom so great as this, they do occur. Unfortunately, the conditions that encourage brief or long response times vary widely and are not clearly described or justified. For example, contrast the long periods of time involved in protocol analysis with the brief periods used in Bayesian judgment tasks, or in tasks in which subjects are required to make judgments about people who are described in 4-5 sentences. Judgment and decision researchers seldom delimit their generalizations about their subjects' cognitive activity with respect to the time dimension.

Predictions. (See Tables 1, 2, 3)

Explanations of the predicted relations between the form of the task and cognitive properties. A posteriori decomposition of cognitive activity induces low cognitive control and related cognitive properties (see Table 2) because it is generally employed in association with a large number of cues contemporaneously displayed in relation to task material for which the subject has no organizing principle. Because such decomposition occurs after a series of judgments has been made, data processing during each trial is generally rapid, and of a low level of awareness. A priori task decomposition, on the other hand, is generally carried out in connection with a priori cognitive decomposition and thus induces slower, more thoughtful choices; the subject is thus more apt to be able to report reasons why one branch of the decision tree is chosen over another. By elevating the process to conscious awareness as a result of requests for a direct, a priori assignment of weights to consciously selected dimensions, the properties of cognition indicated on the right in Table 2 are induced.

In tasks that include continuous cues, less cognitive control is required for utilizing information from continuous gradations than from dichotomous ones. That is, in the case of continuous cues, adjacent scale categories do not often point in different directions, but in the case of dichotomous cues they can and usually do; that is why the information is displayed dichotomously. Therefore, more cognitive control is induced in the latter case than in the former.

The same considerations apply to the judgment categories that the task requires of the subject; continuous response scales induce the cognitive properties on the left of Table 2, dichotomous response scales induce the cognitive properties on the right of Table 2.

Since perceptual measurement induces a largely unconscious form of data processing, less cognitive control can be applied in these circumstances and thus the activities associated with perceptual measurement are less likely to be reported accurately, if at all, and less likely to be those indicated on the right of Table 2 (cf. Nisbett & Wilson, 1977, Ericsson & Simon, 1980). The first effort to test hypotheses derived from Premise 4 provided encouraging results (see Hammond et al., 1984).

Limitations of the Theoretical Framework

Although a wide range of conditions is considered in Premise 4, they are in fact narrow from the larger perspective of those who consider cognition to encompass much more than judgment and decision making. For example, Royce et al. state in their review of psychological epistemology (1978):

> [Judgment and decision] theory and experiment has been given only brief attention for two reasons. The first is that the scope of the theory, by its own definition, relates to only one narrow aspect of epistemology--man's knowing behavior as a statistical scientist, logician, and mathematician. And even in these contexts, intuition is studied only under the conception of "unconscious inference," which ... reduces intuition to the status of a logical cognition below the threshold of awareness. The nature of man's intuiting as an actor, author, artist, or theologian seems somehow qualitatively different from such unconscious inferences. Perhaps this is because statistics (which is the theory's basic conceptual tool), while well suited to precise, repeatable, quantitative, scientific analysis, seems totally incapable of capturing the more qualitative truth of art, music, literature, or metaphysics. The second reason for this brief treatment is the limitation inherent in applying psychological decision theory (which is the theory's basic methodology) to metaphoric behavior and knowledge. (p. 299).

It is also possible to criticize judgment and decision research from a more restricted viewpoint. For example, as Hogarth points out, it is limited mainly to static, not dynamic, changing task conditions (but see Brehmer, 1985; Kleinmuntz, 1985, for recent advances in the area; see also Rouse, 1981, for a review of research in man-machine systems where interactive dynamic tasks are frequently employed). Moreover, it is largely restricted to a single decision maker (but see Brehmer, 1976; Brehmer & Hammond, 1977; Rohrbaugh, 1979, for studies of interpersonal conflict and interpersonal learning) and ignores the subject's involvement in the task, despite McAllister, Mitchell and Beach's (1979) warning that, "when (a) decisions are

more significant, (b) the decision cannot be reversed, and (c) the decision maker is responsible for his actions, then the decision strategy will be more analytic" (p. 228). Unfortunately, none of the conditions cited by McAllister et al. (1979) will be found in Tables 1, 2, and 3 of the present framework.

Although the theoretical framework presented above describes task properties, predicts properties of the cognitive systems induced by these tasks, and predicts their behavioral consequences, neither it nor any other theory can claim to be a comprehensive theory. For example, the relative importance of various task properties is not indicated by the theory, nor does it provide a formula for aggregating several task properties into a prediction regarding which specific cognitive properties and, subsequently, which behaviors will and will not occur. Nor does the theory indicate whether such task properties presented in Table 1 as (a) the articulation of the judgment scale, (b) number of cues, (c) the contemporaneous or sequential presentation of cues should be added, multiplied, or combined in some other way. In short, neither this theory or any other offers a means of predicting the combined effects of several task properties.

Furthermore, it must be noted that conventional research practices are poor vehicles for exploring these contingencies. Such practices break down task conditions but afford no means of accumulating results over task conditions. Achievement of secure, task-independent generalizations will require the methodological shift called for by MacDougall, Brunswik, Newell and Simon, Meehl, and others. That means changing from the nomothetic between-group (including within-subject) design to a full-fledged idiographic-statistical approach that includes the representation of task

conditions derived from the explicit description of task structure described above.

Methodological Innovation

The need for methodological innovation can be illustrated by examining the introduction of new cues into the research literature of psychology. Roughly 30 years ago in a paper presented at a conference on cognition in Boulder, Colorado in 1955, Brunswik (1957, p. 27) summarized the process in this way: "Psychological experiments involving depth perception may be grouped into two major categories, those thriving on a confirming instance of the cue under neglect of the misleading case, and those thriving on the misleading case at the neglect of the confirming case" (p. 27). As an example of the positive case Brunswik notes Gibson's discovery and introduction of the "textural gradient" cue, which provided an additional feature of the ecology which can serve as an aid to accurate perception. As an example of the negative case, he cites the work of the Ames group which provided the widely distorted room to demonstrate how perception can be deceived. But Brunswik notes that in the negative case, the "bleakly distortive experiments [of Ames] ... merely probe into cue utilization, ... stressing the negative side of achievement but failing to reflect it (achievement) proportionately" (p. 28), and are thus highly misleading regarding perception in general. And although Gibson's experiments demonstrated the potential positive ecological value of the textural gradient cue, they also mislead because no other cues, including cues that made a negative contribution, were allowed to compete in the experiment.

Taylor and Thompson (1982) provide a contemporary example of a similar effort. They pursue the question of whether a cue characteristic, "vividness," can mislead or "bias" the receiver. After a review of numerous studies that manipulate one or two variables at a time, they conclude that it would be desirable "to simulate the real world (carry out representative designs?) by creating multiple stimuli competing for attention" (p. 177). As Taylor and Thompson's (1982) review indicates, many psychologists have "thrived," as Brunswik put it, on identifying and demonstrating "the misleading case at the neglect of the confirming case," particularly in the field of social psychology, which has produced a huge literature of human failure, largely attributed to egocentric motivation and/or perception. But this literature is of doubtful value, for it consists of little but a litany of overgeneralizations of results based one-cue-at-a-time perception "experiments," as the review by Taylor and Thompson (1982) demonstrates.

Textbooks, of course, are filled with erroneous conclusions based on these peculiarities, but many psychologists take them seriously. One example from a little-known but highly significant episode in recent history illustrates how a prominent social psychologist brought the overgeneralization of the "misleading case" to the White House during the Eisenhower administration with the serious intention of affecting policy formation. In his interesting and informative personal history, Hadley Cantril describes (1967) how he and his influential colleagues brought the Ames "distorted room" to the White House:

> on the evening of July 4, 1955.... I showed the demonstrations to the President the next morning. Also present were James Haggerty, press secretary, Nelson Rockefeller, General Theodore Parker, and Lloyd Free. The session quickly assumed a relaxed and informal

atmosphere. I asked the President to take a seat while I first showed him the "revolving trapezoid window." This is a demonstration in which a trapezoidal shape that looks like a window frame is continuously rotated by a small motor. But to the observer, the "window" appears to oscillate back and forth. The illusion is due to the fact that we have become so used to rectangular windows that we assume the two ends of the window are the same length; hence if one edge of the window subtends a slightly larger angle on the retina we interpret it as being closer to us than the other edge. For that is the way we have experienced windows all our lives when we were not looking at them head on and when they formed a trapezoid on our retinas. The trapezoidal window is so designed that the longer edge always subtends a larger angle on the retina; hence when one looks at it, this longer edge, though moving, is never seen to go farther away from us than the shorter edge; and so we see it oscillate instead of revolve. And even after a person is shown how the illusion is created and is told the theory behind it, he still sees it oscillate back and forth when he looks at it again. His intellectual knowledge does not change his perception.

When this was finished, the President asked, "Well, doctor, what do you want me to do now?" I then had him sit in front of the "distorted room"--a room which looks quite rectangular when a person sees it from a certain vantage point with one eye, but which in reality is distorted in such a way that it produces the same image on the retina as a normal room. One of the standard procedures in this demonstration is to ask a person to "swat the fly" with a long

wand held in the left hand. The "fly" is simply a black mark painted over one of the windows on the right side of the distorted room. But since the room is so constructed that the left wall is twice as long as the right wall and the back wall comes in at a sharp angle to connect the two, no one ever swats the fly but, instead, runs the wand against the back wall. The point of the procedure is to illustrate that even though we know "intellectually" that the room is distorted in the way it is, this knowledge does not correct the action, since the action is based on the way we perceive the room and the way we have learned to act with respect to such a perception. After three trials in which he missed the fly, the President, after inital spontaneous laughter, became somewhat irritated, put the wand down and said, "Well, doctor, after all I'm not left-handed."

I presented one or two other demonstrations and we discussed their relationship to programs and messages meant to influence people abroad. Eisenhower got all the points quickly. He related that years ago he had almost given up trying to figure out how the other fellow felt. When he he was a young officer in Asia, he said, there was a court-martial case in which a man was being tried for cruelty to a woman to whom he was engaged and with whom he was living. One night the man had told the woman he no longer loved her and threw her out of the house. He was acquitted. The President said he had been shocked at this Oriental conception of justice and remarked to himself at the time: "Boy, but you're a whale of a long way from Abilene, Kansas."

> This occasion, to my knowledge, marks the first time a psychologist, in his professional role, had directly drawn a President's attention to the possible value of psychological theory in Government policy-making. (1967, pp. 18-20).

(Cantril also reports showing these demonstrations to such luminaries as John Dewey, Albert Einstein, Niels Bohr and Konrad Lorenz, all of whom are reported to be enthusiastic about what they saw. The Ames distorted room remains on display at the "Exploratorium," a San Francisco museum devoted to scientific exhibits that was created by Frank Oppenheimer, brother of Robert Oppenheimer, as an example of how normal perception works.)

Thus, Cantril presented the misleading case to Eisenhower, not only to show the important contribution psychological theory and research could make to policy formation, but equally important perhaps, to show "how difficult it is to make people see things differently by means of any purely intellectual, argumentative approach." Moreover, Cantril asserts "any approach should be made in a person's own terms, from the point of view of his experience, his preferences, and his understanding of the proper means to accomplish his ends" (1967, pp. 17-18). However much we might agree with these conclusions (derived more from contemporary folk belief or "pop" psychology than scientific research), and howevermuch we may applaud Cantril's efforts in the interests of international understanding and peace, his attempt is more instructive for what it tells us about the enthusiasm with which social psychologists accept results regarding the infirming case and their willingness to generalize from such cases. (See Christensen-Szalanski & Beach, 1984, for empirical verification of the preference for citing rather than success.)

The difficulties of aggregating results from the conventional research methods inherited from agricultural research illustrated by the Taylor and Thompson (1982) review of the "vividness" effect were anticipated by Koch (1959) in his epilogue to a major review of psychology as a science, in which he called for the development of an "indigenous methodology" for psychology. Hammond, et al. (in press) provide such a methodology by combining the general principles of Brunswik's (1956) representative design with the general principles of Campbell and Fiske's (1959) multitrait-multimethod methodology. In doing so they combine the correspondence (empirical) theory of truth with the coherence (logical) theory of truth. In particular, the convergent and discriminant validity of concepts, independent of method, are evaluated. As a result, the generality of results over conditions is tested as well as the coherence of the conceptual nature of the theory. These goals are achieved by developing a "coherence validity matrix" and a "performance validity matrix" for each subject separately, as well as a means for aggregating the results over all subjects. The coherence validity matrix tests the convergent and discriminant validity of concepts and methods for each subject but does so without reference to performance, i.e., response-criterion correlations. The performance validity matrix takes into account the ecological intercorrelations among the criterion variables, thus bringing an essential element of Brunswik's representative design into the measurement of convergent and discriminant validity--all of which are ordinarily ignored in conventional experimental design. Generalization of results over conditions, methods, and concepts is thus measured separately for each subject. Using these procedures, Hammond et al. (in press), were able to examine the coherence and performance of the expert judgment of each of twenty-one highway engineers with regard to three concepts, three methods and three criteria, as well as

that of an "artificial engineer" created by the aggregation of the data for all subjects.

This methodology is, of course, more complicated than the methodology derived from applied research in agriculture, by which the effect of two or three "treatments" on large numbers of subjects (plants, animals) is evaluated in terms of simple responses (e.g., height or weight change, or reaction time). But it addresses the needs of a science that intends to be grounded on basic research and intends to generalize over conditions.

Conclusion

It can easily be demonstrated that major investigators persistently repeat the use of the same task conditions in their research, although they differ widely in their choice of conditions to study and concepts by which they describe the cognitive activity of their subjects, thus providing a number of "schools" within this area of research (see Hammond et al., 1980). Examination of the ten most recent articles by Norman Anderson, Ward Edwards, Kenneth Hammond, Daniel Kahneman, and Amos Tversky shows that in each case, reference to the work of other authors is rare, and occurs principally in review rather than in empirical research.

Paradoxical as it may seem, persistence of this disparity in conditions may be of great advantage--if the results can be drawn together. For if the various task conditions already studied are found to occupy different points on the cognitive continuum described here, then the results that have already been achieved may turn out to be complementary, rather than simply standing in isolation, as they presently do. Indeed, the cognitive continuum may turn out to be largely explored already. If so, we may know more than we think we do.

But we shall never discover whether that is true or not if we aggregate or cumulate results simply by assertion, as present practices permit us to do. Analytical forms of aggregation that explicitly address issues of convergent and discriminant validity in the context of coherence and performance will be required if we are to achieve the unification of theory and research in the field of cognitive psychology.

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Table 1

Complexity of Task Structure

Inducing Intuition	Inducing Analysis
1. Texture of judgment scale	1. Texture of judgment scale
A. Many alternatives	A. Few alternatives
B. Many steps to solution	B. Few steps
2. Number of cues presented	2. Number of cues presented
A. Many (>5) cues contemporaneously displayed	A. Few (2-4) cues sequentially encountered
3. Vicarious mediation	3. Vicarious mediation
A. Intra-ecological correlations present to large (R = .5) degree (horizontally)	A. Intra-ecological correlations minimal (vertically)
4. Cue distribution characteristics	4. Cue distribution characteristics
A. Normal	A. Peaked
B. Linear function forms	B. Nonlinear, nonmontonic function forms
5. Weights	5. Weights
A. Equal	A. Unequal
6. Organizing principle	6. Organizing principle
A. Linear model	A. Nonlinear model

Table 1 (Continued)

Ambiguity of Task Content

Inducing Intuition	Inducing Analysis
1. Availability of an organizing *principle*	1. Availability of an organizing principle
A. Not available	A. Readily available
2. Task outcome available	2. Task outcome available
A. Not available	A. Readily available
3. Familiarity with content	3. Familiarity with content
A. Not familiar	A. Highly familiar
4. Feedforward	4. Feedforward
A. No training, no information	A. Prior skill, information
5. Feedback	5. Feedback
A. Minimal	A. Cognitive feedback
6. High accuracy	6. High accuracy
A. Not likely	A. Likely

Table 1 (Continued)

Form of Task Presentation

Inducing Intuition	Inducing Analysis
1. Task decomposition	1. Task decomposition
A. A posteriori	A. A priori
2. Cognitive decomposition	2. Cognitive decomposition
A. A posteriori	A. A priori
3. Type of cue data	3. Type of cue data
A. Continuous	A. Dichotomous
4. Type of cue definition	4. Type of cue definition
A. Pictorial	A. Quantitative
B. Subject measures cue levels	B. Objective measures
5. Response time permitted or implied	5. Response time permitted or implied
A. Brief	A. Open

Table 2

Predictions of Cognitive Properties in Single-System Case

Intuitive Cognition	Analytical Cognition
1. Low cognitive control	1. Opposite
2. Unconscious data processing, with regard to weights, function forms, organizing principles	2. Opposite
3. Vicarious functioning (includes shifting cue utilization)	3. Opposite
4. Rapid data processing	4. Opposite
5. Raw data or events stored in memory	5. Complex organizing principles stored in memory
6. Pictorial metaphors predominant; verbal, quantitative metaphors absent	6. Verbal, quantitative metaphors serve as organizing principles and hypotheses; pictorial metaphores absent (or appear only during intuitive phase of problem solving)
7. Right hemisphere activity predominant	7. Left hemisphere activity predominant
8. Stable policy means rigidity	8. Stable judgment subject to change with new information

Table 2A

List of Predictions Regarding Performance in Single-System Case

Intuitive Cognition	Analytical Cognition
1. Inconsistency A. Low predictability of judgments over time B. Logical inconsistency (where appropriate) C. Failure to conform to math axioms (where appropriate)	1. Opposite
2. Lack of retraceability or awareness of process A. Difficulty in verbalizing B. Expressing quantitatively, cognitive activity	2. High degree of retraceability when moving toward solution; when blocked subject often resorts to pictorial representations of thought, or pictorial analogies or metaphors, that are recovered
3. Brief response time A. Other indications of absence of analysis	3. Opposite
4. Low confidence in judgments	4. Opposite

Table 2A (Continued)

List of Predictions Regarding Performance in Single-System Case

Intuitive Cognition	Analytical Cognition
5. Change	5. Change
A. Change in cognitive system limited to change in cue weights as policy formed	A. Change in weights, function forms and organizing principles until stable policy reached
	B. Rapid change occurs with new information
6. Equal weighting of cues over long term (i.e., "matching" rather than "maximizing" behavior)	6. Opposite; weight concept not applicable
7. Linear function forms	7. Opposite
8. Weighted averaging organizing principle (compromise), Note: matching here also	8. Any organizing principle (other than weighted averaging possible)
9. Event memory	9. Memory of principles (including metaphors in creative phases)
10. Right side brain activity	10. Opposite

Table 3

Predictions of Cognitive Properites in Double-System Case

Intuitive Cognition	Analytical Cognition
1. Low cognitive control	1. Opposite
2. Unconscious data processing with regard to weights, feedforward, organizing principles	2. Opposite
3. Vicarious functioning (includes shifting cue utilization)	3. Opposite
4. Rapid data processing	4. Opposite
5. Raw data or events stored in memory	5. Complex organizing principles stored in memory
6. Pictorial metaphors predominant; verbal, quantitative metaphors absent	6. Verbal, quantitative metaphors serve as organizing principles and hypotheses; pictorial metaphors absent (or appear only during intuitive phase of problem solving)
7. Right hemispheric activity predominant	7. Left hemispheric activity predominant
8. Stable policy means rigidity	8. Stable judgment subject to change with new information

Table 3A

Predictions of achievement for Double-System Case

(Note: Predictions of performance from Single-System Case carry forward.)

Intuitive Cognition	Analytical Cognition
1. Slow, 'stupid' learning from inexact (probabilistic) outcomes; e.g., large number of trials to solution	1. Opposite
2. Normal distribution of task errors	2. Non-normal distribution of errors
3. 'Stereotyped,' persistent use of cues	3. Opposite
4. Frequent appeal to event memory for recall of task properties and performance	4. Frequent appeal to organizing principle for recall of task properties and performance
5. Transfer low; tasks with different content	5. Transfer high over differing content
6. Underconfidence (contrast between observed performance and report of confidence)	6. Opposite
7. Inconsistency matches task unpredictability over occasions	7. Inconsistency from trial to trial; not matched to task; maximizing strategy in tasks proven to be stochastic

Figure Caption

Figure 1. Darwin's first three tree diagrams on pages 26 and 36 of the *First Notebook* (from Gruber, H. E., Darwin's "tree of nature" and other images of wide scope. In J. Wechsler (Ed.), *On aesthetics in science*. Cambridge, MA: MIT Press, 1979.).

no only makes it compli[cated] complication
Contradiction

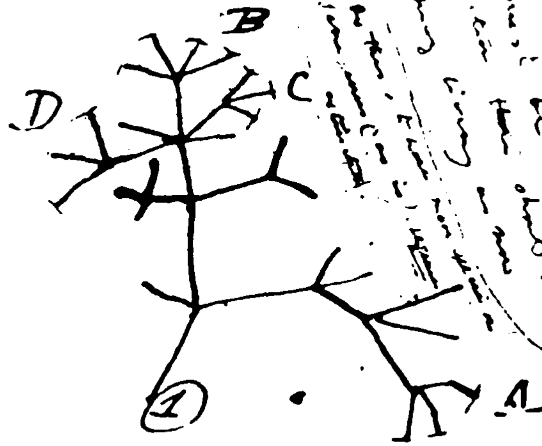
Constant succession
of germs in progress.

Is it thus fish can
be traced right down
to simple organization. —
birds — not.

36

I think

Case must be that one generation then should be as many living as now. To do this & to have as many species in same genus (as is) requires extinction.



Thus between A & B immense
gap of relation. C & B the
finest gradation, B & D
rather greater distinction
Thus genera would be
formed. — bearing relation

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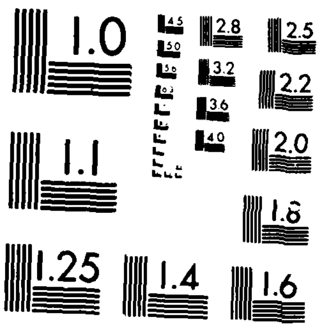

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